Paper ID #20513

The Development of a Freshman Engineering Research Program

Michelle Audrey Pang, Sandia National Laboratories
Dr. Carolyn Conner Seepersad, University of Texas, Austin

Associate Professor of Mechanical Engineering

Dr. Sheldon Landsberger, University of Texas, Austin, Department of Mechanical Engineering

THE DEVELOPMENT OF A FRESHMAN ENGINEERING RESEARCH PROGRAM

Abstract

Incorporating research opportunities into undergraduate engineering education provides students with early hands-on experiences that often influence retention rates and the likelihood of continued research participation and higher education. A new initiative at the University of Texas at Austin (UT Austin), the Freshman Introduction to Research in Engineering (FIRE) program, offers a select group of first-year students with an opportunity to participate in semester-long, faculty-sponsored mechanical engineering research and development projects. In addition to their research, students attend bi-monthly lectures that introduce them to various topics in mechanical engineering and current research in the field, the successes (and roadblocks) in engineering research and how to overcome them, and career opportunities in engineering. An end of semester poster session allows students to showcase their research results and describe opportunities for future work, encouraging continued involvement in research. Many FIRE students continue to participate in research after the program concludes and note that the program influenced their decision to attend UT Austin and confirmed their interest in the field of mechanical engineering. The general structure of the FIRE program is documented in this paper, along with investigations of its impact on participants' GPA, retention within the major, rate of participation in undergraduate research, and intention to pursue higher education. Student perceptions of the program and opportunities for improving it are also discussed.

1. Introduction

Participation in undergraduate research provides students with opportunities to engage in experiential learning by applying material taught in the classroom to real-world applications and problem solving. These experiences allow undergraduate students to take an active role in their education and help to expand students' knowledge base outside of the day-to-day classroom problem sets and exams. Undergraduate research participation and similarly aimed immersive learning opportunities have been linked with increasing student confidence [1] and interest in STEM based careers [2-4], as well as self-efficacy [5,6], and ultimately college and program retention rates [4,5,7,8].

Although the benefits of undergraduate research are significant, the real and perceived barriers to entry for first- and second-year students are often high, despite high levels of personal interest. First- and second-year students often find it difficult to navigate the research world on their campuses and identify suitable research opportunities, and faculty members often select juniors and seniors for undergraduate research positions because they have additional coursework experience. Additionally, most engineering curricula, especially during the first and second year are packed with core math and science classes and foundational engineering classes [10], leaving little room for technical electives or other hands-on engineering opportunities until the junior or senior years.

To address this challenge, the Freshman Introduction to Research in Engineering (FIRE) program in the Mechanical Engineering Department at the University of Texas at Austin (UT Austin) provides authentic research and development experiences for first-semester students. It pairs teams of freshmen mechanical engineering (ME) students with faculty advisors for a semester-long research project. The motivation for institutionalizing the program is to minimize the barriers to entry into organized research for freshmen students, enhance the undergraduate research culture within the department, and increase recruitment and retention rates for incoming students. Carefully cultivated research projects offer first-year students with a unique opportunity to participate in a hands-on engineering project in small groups, but also to work directly with a faculty member (and graduate researchers) during their first semester at UT Austin. The program, now in its third year, may eventually be implemented across multiple engineering disciplines and serve as a framework for future initiatives aimed at increasing undergraduate participation in research. This paper details the motivations, framework, and course content for this newly implemented freshman research program and provides a preliminary assessment of its effectiveness and suggestions for improving its implementation.

2. Background

The FIRE program is inspired partially by the highly recognized Freshman Research Initiative (FRI) in the College of Natural Sciences at UT Austin [11]. FRI is a 9 credit-hour program that allows freshmen students in the natural sciences to pursue independent research projects during the first three semesters of their undergraduate experience. In this large-scale program, several hundred freshman students in the College of Natural Sciences begin their freshman year by enrolling in a research methods course and then transition to a research stream for their second and third semesters, in which they participate in authentic research projects as part of a laboratory group [10]. Students earn course credit that substitutes for required introductory courses in their majors. Although tenured and tenure-track faculty members set the research directions and provide guidance for the research streams, post-doctoral research educators provide day-to-day guidance, instruction, and mentoring, allowing each faculty member to supervise large numbers of undergraduates. This teaching structure allows the program to scale to its present size of hundreds of incoming students per year.

The FIRE program is similar to the FRI program in the sense that it seeks to engage incoming freshmen in meaningful research experiences, but it differs in scale and content. FIRE consists of a 1 credit-hour project course in which students enroll during their first semester, rather than a 9-credit-hour sequence over 3 semesters. The 1 credit-hour option is implemented because the engineering curriculum cannot accommodate extra courses in the first two years, and substituting a research course for other first-year required courses (e.g., mathematics, physics, chemistry, statics) would require the course to cover all of that course's content, severely restricting the nature of the research projects and the time available to work on them. Also, the program is tailored to engineering research objectives that include elements of innovation and technology development, as opposed to discovery (in the natural sciences). Rather than spending extensive periods in a formal teaching laboratory, the students often spend time in the engineering makerspace and/or in the research labs of their faculty mentors. Research projects are conducted in small teams, generally 2-4 students per team, and students are expected to spend approximately 5 hours/week on their research—enough time to make steady progress on their project but not enough time to distract from their other courses. Student projects are sponsored by a faculty research advisor, and either the faculty member or a post-doctoral researcher or graduate student mentor act as their day-to-day point of contact.

By providing students with opportunities for immersive learning in their first college semester, FIRE seeks to engage freshmen in engineering in a more accessible manner, supplementing their required coursework. The research projects are carefully selected and framed not only to cover a broad range of mechanical engineering topics (from biomechanics to combustion to 3D printing) but also to provide opportunities for undergraduate researchers to exercise creative problem solving, design and hands-on skills, self-motivated project management, and teamwork and communication (both amongst their peers and with faculty and graduate students). The project structure is consistent with research by the National Academy of Engineering, which emphasizes creativity, practical ingenuity, leadership, and management, in addition to strong analytical skills as some of the primary characteristics required for successful engineers of the future [12]. FIRE project teams require a minimum of two first-year researchers to facilitate teamwork and collaboration and to provide students with a peer with whom they can collaborate without reservations of seniority. These collaborative teams are intended to not only foster the leadership and management skills emphasized by the NAE but also foster friendships, support networks, and cooperative experiences that can positively impact student attitudes and overall satisfaction [13,14]. FIRE is also consistent with more immersive curricula that have been found to increase student satisfaction and retention rates at various universities [7,8,15-17]. Project-based experiences, like FIRE, that expose students to real-world engineering challenges and practices have also been shown to promote a broader understanding of basic concepts and synthesis of various related disciplines and skillsets [18-20]. Most FIRE projects include an element of creativity, problem-solving, and design and/or fabrication to provide an opportunity for students to create something tangible, an important part of the learning process [21].

Prior research also indicates that opportunities for immersive learning experiences (such as research or hands-on projects) provide students with dynamic, multi-disciplinary learning environments that increase students' self-confidence, self-efficacy, and identification as an engineer [2,6], especially during the first-year [5,10,17]. Accordingly, these programs are likely to have an impact on retention rates, especially amongst underrepresented student groups [5,7,13,15]. A further impact of undergraduate research experiences is increased likelihood of post-baccalaureate degrees and continued interest in STEM careers observed in students who were privy to these experiences as undergraduates [2-4,22].

While undergraduate research programs are not novel, programs that actively engage first-year students are less common. Georgia Tech's Vertically Integrated Projects (VIP) [23] and Faculty Research Projects at the University of Michigan [24] bring together multi-disciplinary teams of undergraduate and graduate students (and faculty, at University of Michigan) to tackle challenging and contextually relevant problems. However, the programs' are not geared specifically to freshmen and projects can often span multiple years, whereas the FIRE program is designed to target first-year students specifically and to serve as an introduction to academic research at the college level. Some universities offering research programs aimed at engineering undergraduates include Penn State University [25], Yale College [26], the University of Michigan [27], the University of Illinois [28], and the University of Pennsylvania [29]; however of these programs, only Penn State's and Yale's are geared specifically towards first-year students. The University of Michigan's College of Literature, Science, and the Arts also offers an undergraduate research program aimed at first and second year students [30]. Other universities such as Iowa State University [31], the University of Maryland [32], and Binghamton University [33] have created programs modeled directly from FRI at UT Austin. Like FRI, research areas are primarily focused around natural sciences, however both the University of Maryland and Iowa State programs advertise some engineering research opportunities. The FIRE program's unique approach involves actively encouraging incoming mechanical engineering students to apply to participate in a freshman research project. The next section describes the FIRE program in greater detail.

3. Description of the FIRE Program

Program Goals. The primary goal of FIRE is to provide first year ME students with experiential learning opportunities in the form of guided research projects. The intent of these experiences is to allow students to get involved in research early in their academic careers, so that they can be better prepared for future research opportunities. The hands-on experience of conducting research also provides first-year students with a chance to put their core curriculum to use on a practical and tangible project, and witness first-hand how to apply math and science to solving an open-ended problem. Additionally, completion of the program and participation in research is intended to bolster applications for graduate school and competitive internships/career tracks as well as increase confidence and interest in the field of engineering [3,4,22] and personal identification with engineering [6]. Professional identity has been studied in STEM fields as a means of understanding the motivations, interests, and expectations of collegiate students [34].

A secondary focus is to improve retention rates and recruitment of students, especially those who are traditionally underrepresented in STEM fields. Prior research shows that students who do not self-identify as engineers are often likely to migrate to other majors [35, 36]. Providing students, especially those in their first-year, with engaging, hands-on experiences, such as research projects, can foster sentiments of inclusion which are often indicative of self-identification [37]. Research projects and other hands-on work serve as "mastery experiences" which Hutchison et al. found has a strong impact on self-efficacy [5].

Opportunities to participate in research for freshmen are both prestigious and rare; the attractiveness of the FIRE program provides the department with a competitive advantage over other top universities. The program helps combat attrition rates that are highest in the first two years of college by providing an ME-intensive course that allows students to apply the required math and science curriculum and promoting early engagement in the field of engineering. Building on the notion of lack of identification with the field of engineering (especially among underrepresented groups [34]), research indicates that freshmen are 1.5 times less likely to identify as engineers compared with sophomores, juniors, or seniors [38], and a review of retention research indicates that students with lower self-confidence and/or self-efficacy are more likely to leave engineering fields [14]. Thus, there is a potential for FIRE to have significant impact on minimizing attrition rates.

By engaging students in research and connecting them with faculty at the beginning of their college careers, FIRE is intended to promote continued participation with research both directly and indirectly. Students who participate in the program have immediate, direct contact with the faculty sponsoring their projects, which often leads to continued involvement in a research lab after the conclusion of the FIRE program. Even if they do not continue their specific research project beyond the first semester, students still have an advantage over their peers because they have successfully completed a semester-long research project and can use their experiences and contacts to seek other research opportunities.

Finally, FIRE seeks to improve students' understanding of engineering by engaging them in discussions about engineering research, career opportunities, and the characteristics of effective and/or successful engineers. Lastly, students showcase their semester-long projects in the form of a team-written report and an end-of-semester poster session, in which student teams present their findings and discuss future work. The poster session helps improve students' technical communication skills, while increasing awareness of the cutting edge research being conducted throughout the department. The written report allows teams to discuss their methods and findings in a more detailed format, and can be useful documentation for instructors as well as the participating research groups.

Participant Demographic and Recruitment. Students are recruited primarily by invitation, but any incoming ME student who inquires about research opportunities is invited to apply. Students submit an application consisting of an essay describing their background interests, motivation for participation, relevant prior experience, and future goals. Essays are reviewed by the faculty and staff, and decisions letters are emailed to students over the summer notifying them of their acceptance for the fall semester. The 2014-2015 and 2015-2016 FIRE programs enrolled 19 participants (10 female; 9 male) and 33 participants (23 female; 10 male), respectively. The large cohort of female participants is attributed to an especially strong effort to market the program among incoming female students, although everyone who applied to the program was accepted.

Program Content and Lecture Schedule. In addition to regular meetings with their project team and faculty advisor, FIRE students attend a 1-hour lecture every 2 weeks. The lectures cover a wide array of topics intended to introduce students to the field of mechanical engineering, effective research methods, graduate school in engineering, and written and oral technical communication (Table 1). The first lecture provides an overview of the various subdisciplines of mechanical engineering and the research projects that are offered for the semester. Students submit requests for their top 5 project choices, citing relevant background or experience. This information is used to match each student with a research project and a team of other students.

By the second lecture, students are informed of their projects and project teams. The second lecture covers engineering methods for conducting research, detailing best practices, available resources, and an overview of the research process. As a homework assignment, a Mentor-Team Charter (Appendix B) is completed by the teams and submitted by the third lecture. This charter is to be completed by the student team, with feedback and input from their faculty and/or graduate student/post-doctoral mentor.

For the third lecture, student teams provide an introduction to their research project for the class, providing relevant background information. Each team is also asked to present their research plan for the semester, milestones, and overall end-of-semester goal for the project.

The fourth and fifth lectures feature guest lecturers discussing academia and research from faculty and graduate student perspectives, respectively. In 2015, the faculty lecture was delivered by a faculty member in the acoustics area of ME, who discussed his lab's research on sound-absorbing devices and his experiences in academia as a professor. Also in 2015, the fifth lecture was hosted by a post-doctoral scholar who recently completed her undergraduate and graduate degrees at UT Austin. She discussed her background, how/why she decided to attend graduate school, why she chose to pursue a PhD, and lessons she learned along the way. The intent of this lecture was to provide students with information about graduate school presented directly by a former student and someone who had recently been in their position. Students were encouraged to ask questions throughout each presentation.

Table 1: Lecture Guide (Fall 2015); a detailed guide to the lectures given during the Fall 2015 FIRE course can be found in Appendix A

Week	Class No.	Lecture Title/Topic
1	1	Topics in Mechanical Engineering & Introduction to Research Projects
3	2	Engineering Methods: Best Practices for Conducting Engineering Research
5	3	Student Presentations: Research Topic and Plan of Work
7	4	Special Topics in Mechanical Engineering: Acoustics (Guest Lecture)
9	5	My Experiences in Graduate School (Guest Lecture)
11	6	How to Create a Research Poster and Write a Research Report
13	7	Holiday – No Lecture
15	8	Student Presentations: Final Research Posters

The final deliverables for the course include a research paper and poster presentation detailing the motivation for their project, their research methodology, results and conclusions, and opportunities for future work. To prepare students for these deliverables the sixth lecture covers the basic details of how to write a research paper and the content and design of a research poster. The various sections of a research report (such as the abstract, hypothesis, introduction, methodology, results, and conclusion) are highlighted to provide students with a framework for their final reports. Guidelines for the research paper (Appendix C) and examples of past research reports (from the previous FIRE course) are made available to the students for reference. Additionally, a list of online resources offering tips for creating attractive and effective research posters and academic writing guides are distributed to further aid in preparing the final deliverables.

The research poster session is held during the last lecture session. Teams present their semester's work in a 7 minute presentation, followed by 3 minutes of Q&A with the audience. Team research reports are also collected at this last meeting. In 2015, the poster session was held in a large common space in the ME building, and all students and faculty advisors were invited to attend. The chair of the ME department, sponsors, and several research mentors were in attendance.

There are opportunities to customize or expand the lecture sequence. For example, in past years, practicing engineers have been invited to give guest lectures on their careers. Other topics could include a guest panel featuring current graduate students, career talks by engineers in the field, or even presentations given by various engineering extracurricular groups and competitive teams (to encourage students to get involved with engineering activities outside the classroom).

Course Deliverables. (i) Project Preferences. Students are required to rank their top 5 research projects and submit a ranked list to the teaching assistant by the end of the first week of instruction. Along with their rankings, students are encouraged to include any relevant background experience (such as FIRST Robotics, math clubs, programming knowledge, or past science/research projects). This information is used to match students with their preferred projects and to help ensure that students are enthusiastic and interested in their research projects. Preference is given to students who have prior experience or skills that are directly applicable to a particular project, but almost all students are allocated one of their top 3 project choices. Teams include 2 to 4 students, depending on the request of the faculty mentor. The team sizes are maintained to mimic other successful outreach programs that seek to foster teamwork and skills development [39]. While projects have been proposed that only request one undergraduate researcher, we have found this experience to be too isolating for the undergraduate student who is assigned to these projects, even if they are exceptionally interested in the topic. One of the intents of the FIRE program is to introduce freshmen to research environments and projects, which are often collaborative efforts.

(ii) Mentor-Team Charter (Appendix B). The intent of the charter is to encourage teams to have an open discussion about goals, responsibilities (individual and team), and general expectations for the semester with one another and with their mentor(s). The written charter also allows teams to agree to a code of conduct with which they are expected to adhere and also to determine team meeting times. A signed copy of this document is submitted to the teaching staff as a reference for the duration of the program.

(iii) Research Background Presentation. Two weeks after teams are formed and students have ample time to meet with their mentors to discuss the background and project details, they provide a 5 minute presentation to the class. This presentation provides background information on the research project, details for what they intend to accomplish during the semester, and a brief overview of their research plan.

(iv) Final Research Poster. Teams present their results and findings during an end of the semester poster session. The poster includes their experimental process or methodology, the results of their semester's work, an analysis of their findings, and proposed future work. Presentations provide the opportunity for students to practice effective oral communication. Teams are given 7 minutes to present, with 3 minutes reserved for Q&A afterwards.

(v) Final Research Paper. In addition to their posters, teams document their semester progress (methodology and findings) and conclusions in a formal research paper. These reports are maintained as a record of the work they accomplished during the semester. Reports can also be used as supplemental information for future teams working on continuations of prior projects under the same faculty in future years. The report also provides students with an opportunity to learn how to write academic research papers and reflect on their semester's work. Guidelines are provided in Appendix C.

Sample Projects and Outcomes. Over the tenure of the FIRE program, a number of projects have been offered, ranging from analyzing human gait to develop a prototype for a prosthetic human ankle to modeling and creating energy models of buildings for predicting energy efficiency measures to designing a fire suppression system. The project offerings selected for each cohort take advantage of faculty expertise while maintaining a balance of theory based analysis (such as generating order of magnitude calculations or researching and assessing existing solutions) and creative problem solving (often via design or hands-on prototyping).

In one project, a team of 3 students designed and fabricated a prototype device that enabled a man with spinal cord injuries and limited hand strength and dexterity to grill burgers again for the first time. The students started by interviewing the man to better understand the problem and the customer's needs to guide their development process. The team created various proof of concept models, sought feedback from their customer (and faculty mentor), and refined their device design throughout the course of the semester. Although they were unable to fully fabricate their device by the end of the semester, several students continued working on the project (without course credit) well into the second semester of their freshman year and created a product that successfully enabled the man to flip burgers on his own (Figure 1). The success of their project caught the attention of the media, and the students were interviewed and featured on a local Austin news program.

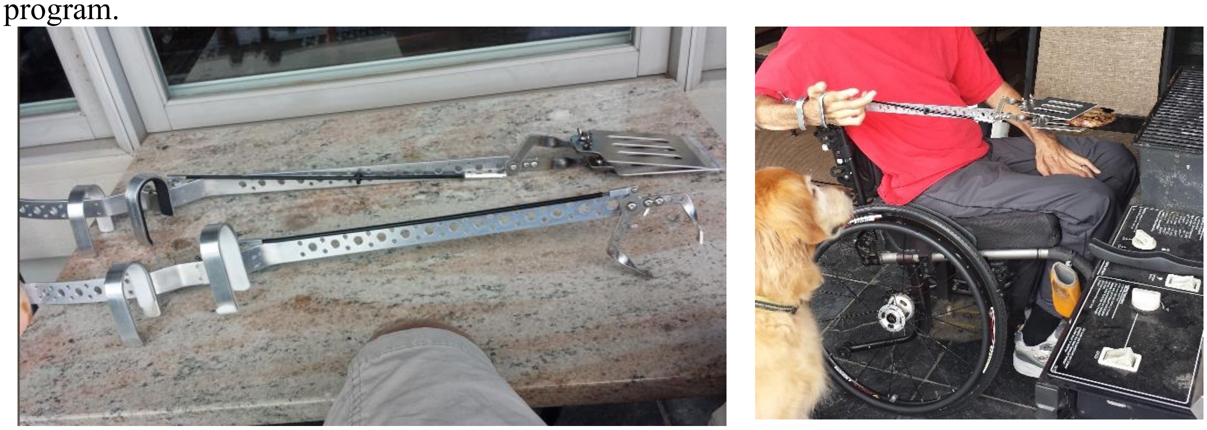

Figure 1. A prototype device for flipping burgers for use by a man with limited hand dexterity.

In another project, a team of 3 students designed, prototyped, and tested fasteners that could be (additively) printed as part of a larger object in order to aid in the assembly process. Students first learned about various additive manufacturing techniques (before ultimately moving forward with fused deposition modeling (FDM) due to the accessibility of 3D printers in the makerspace on campus) and researched different types of fasteners and latches before diving into brainstorming activities, using techniques such as 6-3-5/c-sketching, to create their own custom fastener geometries. The students generated a number of different fastener concepts and then downselected to a smaller number of concepts to be developed further and prototyped. They used low resolution prototypes to test for usability and effectiveness and refined their designs for final prototyping using the 3D printers. The fasteners could be either permanent or reusable and the students explored concepts in both realms. Their designs leveraged existing fastener mechanisms as well as bio-inspired designs, all of which were modified to be suitable for 3D printing.

Course Preparation. The faculty and staff who organize the FIRE program begin preparing for the course several months ahead of time. One of the first tasks is to secure funding for the course. While faculty advisors and post-doc and grad student mentors volunteer their time, funding is needed to provide supplies for the student projects and to support a TA who helps administer the course. On average, a few hundred dollars per project are required, with some projects requiring more funds and some less. In this case, corporate sponsorship covered these funds for the FIRE course. A TA was supported by a special teaching fellowship provided by the provost's office and by support from the department.

The administrative team begins recruiting potential candidates to apply to the program at least 3-4 months before the start of the fall semester. In recruitment information, it is useful to provide a rough outline of the structure of the program, including objectives and goals. Applications are collected 2-3 months before the semester begins so that staff have ample time to review applications and reach out to applicants to inform them of final decisions (students should be notified at least 2 months before the start of the semester, to minimize scheduling conflicts when registering for classes).

The administrative team contacts potential faculty mentors 1-2 months before the beginning of the semester, inquiring about their availability and interest in participating. Interested faculty provide a short overview of their proposed project, and the administrative team discusses the details of the research project and expected outcomes with the faculty to ensure that projects are reasonably complex given the timeframe of the course. Given the limitations of the course and the participants, certain projects may require refinement if they are too broad or too complex (considering resources and educational background). It is important to remember that students will realistically not have a true full semester to complete the projects—1 to 2 weeks of instruction time is lost to project selection. On the other hand, it is important to avoid projects that are overly simplified or too constrained because the intent is to provide students with an opportunity to participate actively in a research activity. Participating faculty are also encouraged to find a suitable graduate student or post-doctoral researcher to act as the primary point of contact for student teams. This reduces some of the burden on the faculty member and provides graduate students and/or post-doctoral researchers with valuable mentoring and teaching opportunities.

The administrative team follows up with faculty advisors 1-2 weeks before the start of the semester to ensure that they are still available to serve as mentors and to finalize project summaries. The project summaries and advisor names are presented to the students during the first lecture.

One week prior to the beginning of the semester, the administrative team contacts accepted students to remind them of the first lecture of the semester and to answer any last minute questions they may have. Research project summaries are circulated to the students prior to the first lecture so that they can begin reviewing the available research projects, do some preliminary research, and prepare questions to ask on the first day of class. Students are advised *not* to contact sponsoring faculty mentors directly prior to the team assignments to avoid an onslaught of queries from students who may not be assigned to the project in the end.

4. Preliminary Assessment of the Impact of the FIRE Program on Participants

Surveys, focus groups, and statistical research were conducted to assess the impact of the FIRE program on the participants in the first two years of the program (2014-2015 and 2015-2016). Data gathering focused especially on the impact of the program on: GPA, retention, participation in undergraduate research, interest in graduate school, student perceptions of the program, and opportunities for improving the program.

4.1 Retention

As of December 2016, 50 of the 52 students who enrolled in the first two years of the FIRE program were still enrolled in the ME undergraduate degree program, for a retention rate of 96%. In comparison, the first-year retention rate for ME students entering the program in 2014 (the first year in which the FIRE program was offered) was 93%, and the two-year retention rate for ME students entering the program in 2013 was 86%. It is important to note that ME department retention rates have been climbing rapidly in recent years (the 2-year retention rate was only 70%, for example, for students entering the program as recently as 2009). These rising retention rates are attributed to a number of changes in the curriculum and enhanced support programs and interventions, including FIRE, so it is quite possible that FIRE is contributing to this increase in retention rates. However, only about 10% of students who entered the ME program in 2014 and

2015 participated in FIRE, and the difference between FIRE retention rates and the first-year retention rates of the ME population at large are not particularly large and might be attributed to the larger percentage of honors students in FIRE (40%) relative to the ME population at large (approximately 10%).

4.2 GPA

As of December 1, 2016, the average GPA for the first 2 cohorts of FIRE students remaining in the ME program (N=50) was 3.63. In comparison, the average GPA of all undergraduate ME students was 3.39 and that of undergraduate ME honors students was 3.82. Since 20 of the FIRE students are in the honors program, a composite GPA for comparison to FIRE students can be constructed by weighting the GPA of ME honors students according to their distribution in the FIRE cohort, as follows:

$$GPA_{composite} = \frac{20}{50} GPA_{ME\ honors\ students} + \frac{30}{50} GPA_{all\ undergraduate\ ME\ students} = 3.56$$

Therefore, the GPA of the FIRE students was slightly higher than the GPA of a similar mix of honors and non-honors students in the ME population at large. The difference between the average GPA of the FIRE students and all undergraduate ME students is statistically significant with a P-value less than 0.001, but the difference between the average GPA of FIRE students and the composite GPA is not statistically significant. Therefore, we conclude that students in the FIRE program earn higher grades than the ME population at large, but they do not perform better than their peers when we account for the significant percentage of honors students in the FIRE program.

4.3 Participation in Undergraduate Research and Interest in Graduate School

Shortly after the end of each FIRE program, the FIRE participants were surveyed anonymously to gauge their participation in undergraduate research and their interest in graduate school. The first cohort completed the program in December 2014 and was surveyed in September 2015; 12 out of 19 students responded. The second cohort completed the program in December 2015 and was surveyed in January 2016; 14 out of 33 students responded. The third cohort completed the program in December 2016 and was surveyed on the final day of class; all 38 students responded to the survey. Results of the surveys are recorded in Tables 1 and 2.

For comparison with the results in Tables 2 and 3, the authors gathered data on the percentage of all ME undergraduates participating in research and the percentage of ME undergraduates transitioning to graduate school in engineering upon graduation. ME department statistics, based on surveys of graduating students, indicate that approximately 10% of ME graduates attend graduate school in engineering immediately after graduation. To estimate the percentage of ME undergraduates participating in undergraduate academic research, the authors surveyed more than half of ME professors personally, identified the number of undergraduate researchers working for each professor, calculated the average number of undergraduate researchers per professor, multiplied the average by the number of professors in the department, and estimated that 194 students were participating in undergraduate research in the spring semester of 2015, or about 17% of the ME student population.

Relative to the ME population as a whole, FIRE students are at least twice as likely (for the 2015-2016 cohort) and as much as four times as likely (for the 2014-2015 and 2016-2017 cohorts) to show interest in attending graduate school. A possible explanation for this remarkable increase in graduate school interest is the exposure of the FIRE students to graduate level researchers and mentors as part of their FIRE projects. Most of the students work closely with graduate students, post-docs, and/or professors, and quite a few spend time in research labs, exposing them to graduate level research and apparently piquing their interest in it.

Relative to the ME population as a whole, FIRE students are more than 3 times as likely to participate in undergraduate research. Several of the students who continued to participate in research after the FIRE program are working with the professors who mentored their FIRE projects. Most of the students who were not participating in undergraduate research at the time of the survey indicated that they planned to do so in the future. In discussions and freeform survey responses, students who had not yet participated in post-FIRE undergraduate research cited barriers such as busy class schedules and lack of confidence in approaching a professor about a potential research position. Some also cited lack of knowledge about existing research opportunities and not knowing where to look for interesting research projects as barriers to continuing research, as well. However, the substantial participation and interest in undergraduate research among former FIRE students gives a strong indication that the program is beneficial in not only supporting and promoting student interest in research, but also in providing access to research opportunities, either directly (continuation of FIRE projects) or indirectly (giving students the confidence and background to find research opportunities on their own).

Table 2. Percentage of FIRE students who participate or intend to participate in undergraduate research after the FIRE program ends.

Cohort	Actually Participating in Undergraduate Research Post-FIRE	Intend to Participate in Undergraduate Research in the Future	Either Participate or Intend to Participate in Undergraduate Research Post-FIRE
2014-2015	50%	50%	100%
2015-2016	57%	29%	86%
2016-2017	NA	79%	NA

Table 3. Percentage of FIRE students who are interested in graduate school.

Cohort	Plan to Attend Graduate School in Engineering	Plan to Attend Graduate School in Another Field
2014-2015	40%	10%
2015-2016	21%	7%
2016-2017	47%	13%

4.4 Student Perceptions of Engineering and the Potential Impact on Project Formation

To better understand the traits that incoming first-year engineering students most associated with the engineering process, researchers surveyed the FIRE cohorts from 2015-2016 and 2016-2017. Students were asked to spend 15-20 minutes (maximum) composing a short (less than 500 words) response to the prompt, "What does it mean to think like an engineer?" They were expressly asked not to search the internet or otherwise discuss the prompt with others. The intent of these explicit instructions was to elicit students' true opinions without influence from outside sources. The question was designed to elicit students' perspectives on the characteristics of successful engineers, which could be a combination of factors that attracted them to engineering and abilities they would like to acquire as an engineering student.

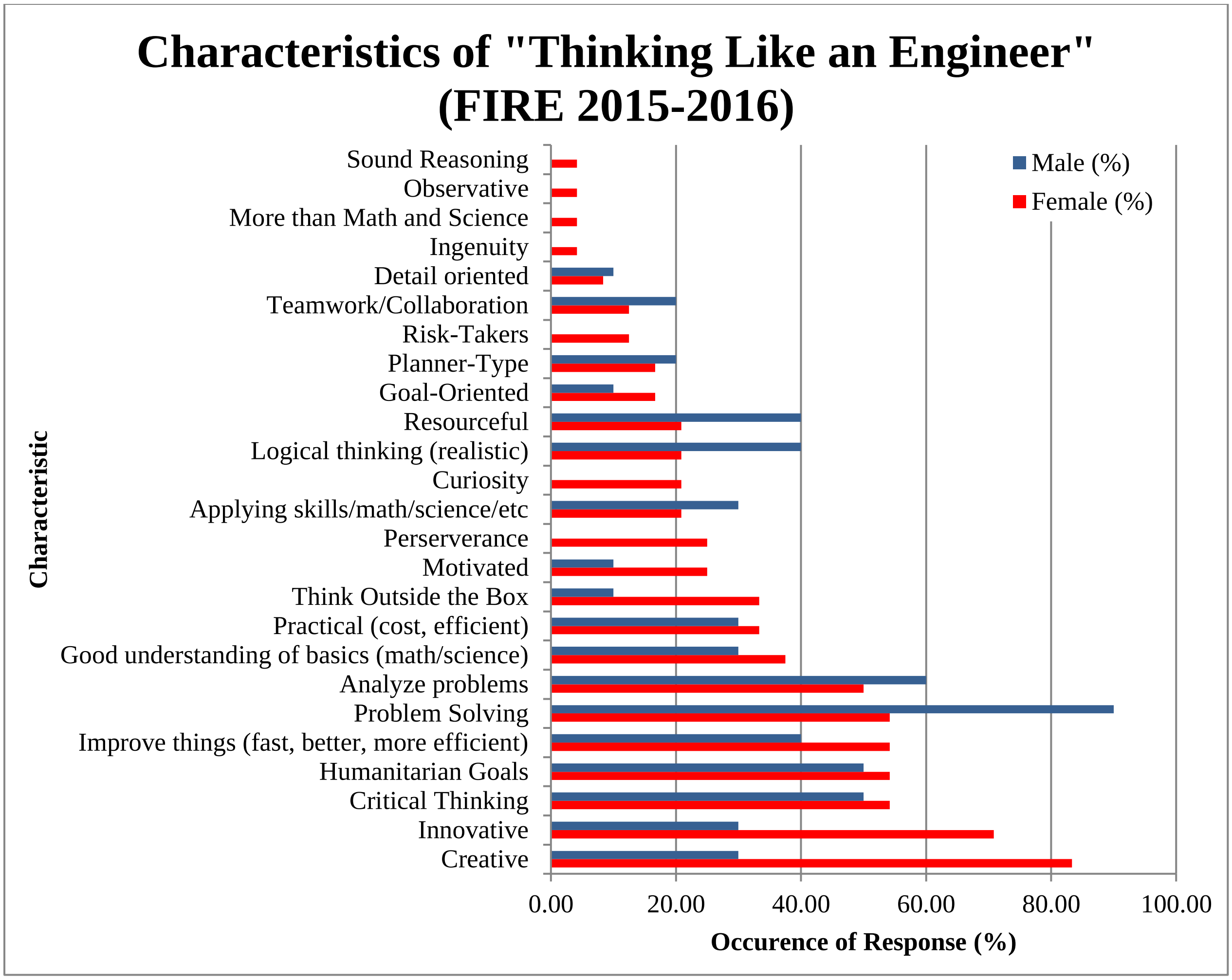

Figure 2: Characteristics from FIRE 2015-2016, based on gender

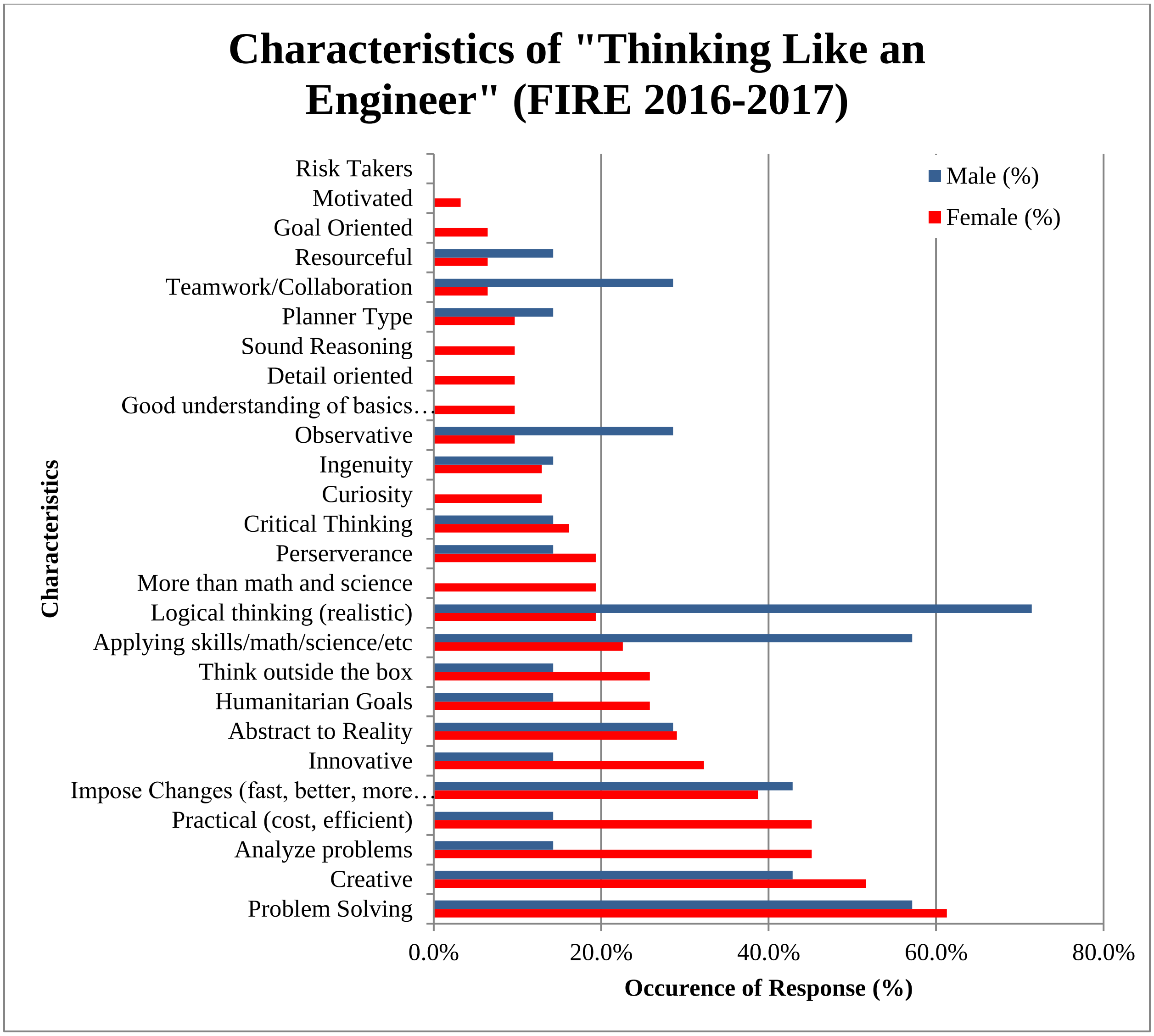

Figure 3: Characteristics from FIRE 2016-2017, based on gender

Content analysis was applied to the results of the survey to track the number of occurrences of particular phrases or terms that are relevant to engineering and engineering thinking, such as creativity, curiosity, and problem solving. Each essay was analyzed using keyword searches to identify commonly used terms and phrases. Words such as "the," "and," "I," and "a/an" were excluded from the analysis; words like "think" and "believe" were also discarded as they offer little insight into the characteristics of engineering thought. In particular, nouns and verbs that pertain, in context, to engineering and how the writer believes engineers think were recorded. If terms appeared multiple times in an essay, they were tallied only once for that essay, indicating that the term appeared in that essay. When all of the engineering-related terms were compiled from all of the essays, synonymous terms were combined (e.g., solve problems and problem solving; teamwork and collaboration). Finally, the percentage of students who mentioned each term was tallied, and the results were reported separately based on gender to recognize any differences between the two groups.

Results of the two surveys are documented in Figures 2 and 3. It is interesting to observe that some of the most common responses include creativity, innovation, problem-solving, improving things, finding practical solutions, and pursuing humanitarian goals. It is also interesting to observe that female students mention creativity, innovation, and curiosity more than their male peers, indicating that design and innovation-related projects may be more appealing to them. It is also interesting to note that some of the most frequently mentioned characteristics are problem-solving and analysis, on one hand, and creativity and innovation on the other hand. These results indicate that it is important for projects to combine rigorous analysis with creative design to challenge and appeal to a broad cross-section of students. In some ways, ideal FIRE projects may be shorter versions of senior design projects. Additionally, one of the aspirations of the FIRE program is to enhance the formation of engineering identity among participants, as engineering identity has been shown to impact overall student satisfaction and retention [5,34-36]. By identifying and recognizing the traits or characteristics that students, especially incoming classes, identify as being the most important or necessary to being/becoming an engineer, research projects and objectives can be carefully framed to best align with student perceptions of engineering identity.

4.5 Student Perceptions of the Program and Opportunities for Improving the Program

Student perceptions of the FIRE program were gathered with focus groups and surveys. An informal focus group was conducted with a handful of students (4 females and 1 male) from the 2014-2015 cohort in January 2015. Students participated voluntarily in exchange for pizza, and the session was conducted by a graduate student who later served as a TA for the course. Feedback from the 2015-2016 and 2016-2017 FIRE cohorts was gathered via in-person discussions between the TA and students partway through the semester and anonymous online surveys conducted at the end of the semester. In all cases, the TA recorded the discussion anonymously and sanitized the responses so that they could not be linked to a particular team or a particular advisor.

2014-2015 Cohort: Overall, the students felt very positively about their experiences in FIRE. Several stated that the opportunity had given them a chance to understand why their early math and physics classes were important and that they appreciated having an engineering-specific course to help them learn more about engineering. Students expressed that completing the program gave them confidence in their abilities as developing engineers, so they were less hesitant about approaching a professor to inquire about research opportunities, because they now had relevant experience . One participant commented that working on the research project and applying math and science to interesting design challenges was really exciting and that as they progressed through the semester they began to see the full capacity of their knowledge because they could not only talk intelligently about their project, but also understand the other projects and even provide suggestions or feedback.

While the experience was described as beneficial overall, three of the participants commented that they wished that their projects had either been more complex or more hands-on and physically applied. Regarding the former comment, students said that some projects were over defined, which led to projects with little opportunity to brainstorm their own ideas, make design choices, and create prototypes to test their concepts. Instead, the tasks and primary objectives for these projects were fully determined by the time students started, making it difficult for teams to feel that they had truly been involved with the "engineering process." When pressed to consider the time constraints of the semester and what could feasibly be accomplished by a small team, participants nodded in agreement that given the length of a semester, some projects may have needed to be more constrained in their planning and definitions than others. However, a few of them said they would not have been opposed to participating in a yearlong program instead of a single semester.

2015-2016 Cohort: The mid-semester discussions with students indicated that the majority of teams felt confident in their ability to complete what they had set out to do as well as create both a presentation and report detailing their work. A couple of teams expressed some concern with being able to finish their project in time (with the main cause for concern stemming from designs not working as anticipated or having broken something during testing). Despite these concerns teams still felt they would have something of value to present at the end of the semester. One suggestion that was made repeatedly by several teams was that they would like a resource list or perhaps a class forum where they could easily share resources and information with others in the class. The content or subject of this list or forum was not cohesively apparent, but when the TA suggested a repository of online reference guides, tutorials, and/or component and hardware shops, the students agreed and said that they had, as a team, created Google documents to share useful websites and tools with one another.

All teams indicated that they enjoyed their projects and were having good interactions with mentoring staff, either the professor or appointed post-doc or graduate student. No team members indicated to the TAs independently that they were having individual teaming or project-related issues; however, in the end of semester feedback survey, one respondent did claim that workload was not equally shared amongst teammates and that two members of their team essentially wrote the entire report themselves. The prevalent suggestion from 2015-2016 following completion of the course was for more structure and outlined deliverables with dates. However, the intention of purposely not providing strict deadlines and milestones was to avoid dictating how students approached their individual projects, which varied widely in content and scope. The students agreed that these deadlines and achievement markers should be set by the researchers and their advisors, so they could be customized to the project. This rationale for this intention could be made more explicitly clear at the start of the semester so that students and mentors make efforts to create their own schedules—and milestones have already been incorporated into the Student-Mentor Team Charter (Appendix B). The second most common suggestion voiced by students was that they would have appreciated having more advanced projects. None of the respondents however elaborated on what type of challenge they felt was lacking in their project, whether that was subject matter complexity, design work, implementation, or testing and analysis.

2016-2017 Cohort: Mid-semester TA discussions with the teams showed that the teams were, as a whole, enjoying their research projects and learning a great deal about their area of focus. Two teams commented that they wished they had been provided with more background material to facilitate their understanding of the area of research and their specific project—one student said that while they had been given a detailed report at the start of the project, the paper was lengthy and difficult to understand. About half of the teams said that they met or interacted semi-regularly with the professor leading their project, but the majority of teams said that they worked primarily under the guidance of a graduate student or a post-doc. Of the 10 teams interviewed, only one team mentioned that they had yet to meet with their sponsoring faculty, however they said that a graduate student working for that professor was meeting with them regularly. While members of two teams mentioned that they had anticipated more mentorship, either from a professor or from a post-doc or graduate student, the students generally felt well supported in their research endeavors. Every team indicated that they had learned at least one (but more often several) new things about (mechanical) engineering, whether that was related to specific subject matter (such as fluids or thermodynamics) or a skill like computer-aided design or the basics of a programming language.

Several students mentioned that they were not yet enrolled in the first-year drafting and computer aided design course, so their experience in FIRE was particularly exciting because it introduced them to SolidWorks before they had even taken the class. Roughly 1/3 of the teams from this year commented on the theoretical versus applied nature of their project. While the comments were not wholly positive or negative towards either type, the general consensus was that applied projects, which often had a clear end goal (a prototype or final design), were a bit constrained and could have been more challenging (perhaps by asking the students to not only design and/or prototype, but also to complete some analysis of their end product. Projects that were more theoretical in nature were harder for students to dive into, because often the theory behind the project or the engineering principles involved were unfamiliar to students in their first semester. In these cases however, the students felt that their mentor(s) were responsive to questions and otherwise helpful and encouraging. Members of two different teams made a suggestion that they would have liked to have a mid-semester project update from their classmates, when they could have shared their progress and sought feedback. Additionally, students told the TA that while they interacted regularly with their team, they would have liked to get to know their classmates as well, and the bi-monthly lecture schedule made it difficult to get to know others outside of their group. There was little indication of any distress amongst the teams during the mid-semester check-ins; however, a few students approached the instructor privately to discuss team members who were not contributing or actively participating. An end of semester survey revealed that at least two students felt that some or all of their team did not contribute equally.

In the survey conducted at the end of the semester, students offered suggestions for improving the experience of future FIRE cohorts. The most frequently occurring suggestion was to extend the length of the course to at least a year-long project. This aligns with the comments from the inaugural FIRE class, and indicates that there is definite interest in and willingness to commit to a longer project. Another suggestion (or comment) was that students felt it would have been beneficial for all of them to have been enrolled in the first-year drafting course concurrently with FIRE, since nearly every project had an element of design.

5. Conclusions and Continued Development

Following three successful pilot sessions within the ME department, there is significant momentum and growing interest to continue offering and expanding the FIRE program within the department. Results from the first three years of the program show that the retention rate of FIRE alumni is 3% higher than the retention rate of students who entered the program in 2014 when FIRE was first offered. The average GPA of FIRE students compared with the broader ME popular was 7% higher, however, when normalized to account for the disproportionate percentage of honors students in FIRE (40%) compared with the general ME population, the difference in FIRE alumni GPAs is not statistically significant. Potentially, the most evident impact of FIRE is on students' attitudes towards graduate school and their interests in participating in academic research. FIRE students are more than three times as likely to express interest in attending graduate school, than their peers. FIRE students are more than three times as likely to be actively involved with or have interest in participating in research during their undergraduate career. While it is still early to ascertain the full impact of FIRE and its benefits both to students and to the ME department, the initial assessment of the programs' effects on students is positive and encouraging with regards to its goals.

In addition to the statistics, feedback from students indicates that the course has a positive impact on student confidence and interest in engineering disciplines. Former FIRE students stated that they were more likely to approach a professor about opportunities to participate in research following the program. Student testimonials provided evidence that the program supplements first year curriculum, by providing hands-on and applied engineering opportunities when most academic schedules are dominated by foundational math and science courses. Students who were unable to enroll in the first year CAD class felt that without FIRE in their first semester, they would have been behind their peers, therefore the program was beneficial in multiple capacities. Participants in each cohort mentioned either in focus groups or during informal conversations with the TAs that the program was influential in their decision to attend UT Austin because the FIRE program allowed them to get involved with research earlier than at other universities.

Further work is required to ensure that continued progress and achievement of milestones, such as reaching out to the greater incoming ME population and increasing the size of each subsequent cohort, are being accomplished. End of semester surveys continue to provide useful feedback and data on student efficacy. Focus groups should be conducted the semester following the end of each program in order to further assess how the program is being received and where improvements can be made from a project, mentorship, or program structure standpoint. This information can be useful in determining what aspects of the course are exceeding student expectations as well as what areas can be improved in order to provide a more beneficial experience. Surveys conducted anonymously directly at the end of the semester are easily administered with high completion rates, whereas focus groups are better held slightly after the course, when students have not only received their grades, but had a chance to reflect on their experience in the program.

Based on the information gathered after each of the initial three offerings, teaching staff have successfully increased the number of projects offered to match the size of the incoming cohort. The projects have evolved each semester to better match the expressed interests of students (both in terms of subject matter and research objectives) and in response to feedback that previous classes have provided regarding the scope, deliverables, and skills that have proven to be useful even after the project ends. Teaching staff are considering how to best create a resource bank that is diverse but easy to navigate or a Wiki or similar type of forum for each cohort where students can choose to share resources amongst themselves. Other suggestions made by students in prior years included having mid-semester progress presentations by each team to not only share their work, but receive feedback, as well. Peer and advisor evaluations of student progress at mid-semester and end-of-semester check points will be implemented in future FIRE offerings to hold all students accountable for their contributions to a team effort. Suggestions that impact degree plans, such as ensuring that all FIRE students are also enrolled in the CAD class or increasing the time requirement for research projects (and thus the number of units given for the course) require additional research and in-depth discussion with university administration and the department.

It is of interest to continue following the progress of each year's cohort as they progress through their undergraduate degrees (whether they stay in ME or otherwise) and to monitor how the FIRE experience may have shaped or impacted their education or outlook on participating in research. As the inaugural FIRE cohort finishes their junior year, it will be particularly interesting to reengage with these students to learn about their undergraduate experiences and their post-graduation plans, especially in comparison with the greater ME population at the university. Another focus group or individual interviews with this class of students before they graduate would provide direct insight into the impact of FIRE. Those students who left the major and or the college of engineering would also be of interest to learn what influenced their decision to change majors.

Conversations with these students could also provide invaluable insight into what factors could (or would) have potentially prevented their decision to leave the field of engineering, and serve as a basis for evaluating the structure of the curriculum, with particular focus on first and second year classes.

Administrators are considering scaling the program to provide opportunities for larger numbers of freshman engineering students. However, participation numbers must be scaled alongside the number of faculty-sponsored research projects available and the funding available to support student projects. Projects will continue to be solicited from faculty who have both time and interest in mentoring first year students. Along with identifying additional faculty research support, the FIRE team will work with interested faculty to develop research projects that are both beneficial to the professor's research goals, and enriching and satisfying for students. Student experiences may be enriched by extending the program to a full (2-semester) academic year. Finally, by documenting the FIRE program, both the design of the program as well as its results, the FIRE team hopes to encourage other engineering departments, within the university and beyond, to implement similar programs.

ACKNOWLEDGMENTS

The authors would like to gratefully acknowledge the Department of Mechanical Engineering within the Cockrell School of Engineering at The University of Texas at Austin for its support and sponsorship of this initiative. In particular, we wish to thank Dr. Jayathi Murthy for her commitment to improving opportunities for ME students, Dr. Sheldon Landsberger for his instrumental role in establishing the FIRE program, Dr. Michael Starbird of the Department of Mathematics for his guidance and mentorship, and Marisa Schmidt and Gillian Hagamen for providing marvelous administrative support in bringing this program to life. Dr. Maura Borrego and Dr. Stephanie Corliss provided valuable feedback on surveying the students. The Provost's Teaching Fellowship program provided invaluable resources for building and tracking the program. We extend our thanks to the ME faculty who sponsored research projects and served as mentors. We are also grateful to Phillips 66, who provided financial support for the student projects.

References

[1] Lopatto, D., 2003, "The essential features of undergraduate research,'" *Council of Undergraduate Research Quarterly,* Issue 24, pp. 139-142.

[2] Russell, S.H., Hancock, M.P. and McCullough, J., 2007, "Benefits of undergraduate research experiences," *Science (Washington)*, *316*(5824), pp. 548-549.

[3] Lopatto, D., 2007, "Undergraduate research experiences support science career decisions and active learning," *CBE-Life Sciences Education*, *6*(4), pp. 297-306.

[4] Hathaway, R.S., Nagda, B.A. and Gregerman, S.R., 2002, "The relationship of undergraduate research participation to graduate and professional education pursuit: an empirical study," *Journal of College Student Development*, *43*(5), p. 614.

[5] Hutchison, M.A., Follman, D.K., Sumpter, M. and Bodner, G.M., 2006, "Factors influencing the self-efficacy beliefs of first-year engineering students," *Journal of Engineering Education*, *95*(1), pp. 39-47.

[6] Hunter, A.B., Laursen, S.L. and Seymour, E., 2007, "Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development," *Science Education*, *91*(1), pp. 36-74.

[7] Gregerman, S.R., Lerner, J.S., von Hippel, W., Jonides, J. and Nagda, B.A., 1998, "Undergraduate student-faculty research partnerships affect student retention," *The Review of Higher Education*, *22*(1), pp.55-72.

[8] Fortenberry, N.L., Sullivan, J.F., Jordan, P.N. and Knight, D.W., 2007, "Engineering education research aids instruction," *Science-New York then Washington*, *317*(5842), p.1175.

[9] ABET Board of Directors, "Criteria for Accediting Engineering Programs," 1 November 2014. [Online]. Available: http://www.abet.org/wp-content/uploads/2015/05/E001-15-16-EAC-Criteria-03-10-15.pdf. [Accessed 7 2 2017].

[10] Beckham, J.T., S.L. Simmons, and G.M Stovall, 2015, "The Freshman Research Initiative as a model for addressing shortages and disparities in STEM engagement," in *Directions for Mathematics Research Experience for Undergraduates (M.A. Peterson, Y.A. Rubinstein, Eds.),* World Scientific.

[11] "Freshman Research Initiative." *Freshman Research Initiative*. College of Natural Sciences, The University of Texas at Austin, 2015. Web. 9 Feb. 2017.

[12] Clough, G.W., 2004, "The engineer of 2020: Visions of engineering in the new century," *National Academy of Engineering, Washington, DC*.

[13] Besterfield-Sacre, M., Atman, C.J. and Shuman, L.J., 1997, "Characteristics of freshman engineering students: Models for determining student attrition in engineering," *Journal of Engineering Education*, *86*, pp.139-150.

[14] Geisinger, B.N. and Raman, D.R., 2013, "Why they leave: Understanding student attrition from engineering majors," *International Journal of Engineering Education*, *29*(4), p.914.

[15] Froyd, J.E. and Rogers, G.J., 1997, "Evolution and evaluation of an integrated, first-year curriculum," In *Frontiers in Education Conference, 1997. 27th Annual Conference. Teaching and Learning in an Era of Change. Proceedings.* (Vol. 2, pp. 1107-1113). IEEE.

[16] Corleto, C.R., Kimball, J.L., Tipton, A.R. and MacLauchlan, R.A., 1996, "Foundation coalition first year integrated engineering curriculum at Texas A&M University-Kingsville: development, implementation and assessment," In *Frontiers in Education Conference, 1996. FIE'96. 26th Annual Conference., Proceedings of* (Vol. 3, pp. 1141-1145). IEEE.

[17] Knight, D.W., Carlson, L.E. and Sullivan, J.F., 2007, "Improving engineering student retention through hands-on, team based, first-year design projects," In *Proceedings of the International Conference on Research in Engineering Education*. Honolulu, HI.

[18] Al-Holou, N., Bilgutay, N.M., Corleto, C. and Demel, J.T., 1999, "First-year integrated curricula: Design alternatives and examples," *Journal of Engineering Education*, *88*(4), p.435.

[19] Froyd, J.E. and Ohland, M.W., 2005, "Integrated engineering curricula," *Journal of Engineering Education*, *94*(1), pp.147-164.

[20] Grigg, N.S., Criswell, M.E., Fontane, D.G., Saito, L., Siller, T.J. and Sunada, D.K., 2004, "Integrated civil engineering curriculum: Five-year review," *Journal of Professional Issues in Engineering Education and Practice*, *130*(3), pp.160-165.

[21] Crawley, E.G., Malmqvist, J., Ostlund, S., Brodeur, D.R., Edstrom, K., 2007, *Rethinking Engineering Education, The CDIO Approach*, Springer International Publishing, Switzerland.

[22] Seymour, E., Hunter, A.-B., Laursen, S. L. & Deantoni, T., 2004, "Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study," *Science Education,* 88(4), pp. 493-534.

[23] "VIP - the Vertically Integrated Projects Program | VIP." VIP - the Vertically Integrated Projects Program | VIP. Accessed May 18, 2016. http://www.vip.gatech.edu/vip-vertically-integrated-projects-program.

[24] "Faculty Research Project Teams." Multidisciplinary Design Program. February 08, 2017. Accessed February 8, 2017. http://mdp.engin.umich.edu/faculty-research/.

[25] "Undergraduate Research." Penn State Engineering: Undergraduate Research. Accessed February 10, 2017. http://www.ime.psu.edu/research/undergraduate-program.aspx.

[26] "Yale College." Yale College Freshman Summer Research Fellowship in the Sciences & Engineering | Science & Quantitative Reasoning. Accessed May 18, 2016. http://science.yalecollege.yale.edu/yale-college-freshman-summer-research-fellowship-sciences-engineering.

[27] "RISE: Research, Innovation, Service and Entrepreneurship." RISE: Research, Innovation, Service and Entrepreneurship | UM Department of Mechanical Engineering. Accessed February 8, 2017. http://me.engin.umich.edu/academics/rise.

[28] "Undergraduate Research." Undergraduate Research - Engineering at Illinois. Accessed May 18, 2016. http://engineering.illinois.edu/research/undergraduate/.

[29] "Undergraduate Research." Penn Engineering - Undergraduate Research. Accessed May 18, 2016. https://www.seas.upenn.edu/undergraduate/research/.

[30] "Fall-Winter Programs." Fall-Winter Programs | U-M LSA Undergraduate Research Opportunity Program (UROP). Accessed February 8, 2017. https://lsa.umich.edu/urop/students/fall-winter-programs.html.

[31] "Iowa State University." *Freshman Research Initiative*. Iowa State University, n.d. Web. 10 Feb. 2017.

[32] "FIRE." FIRE: The First-Year Innovation & Research Experience @ UMD. Accessed February 10, 2017. http://fire.umd.edu/index.html.

[33] “Freshman Research Immersion.” Binghampton University – Freshman Research Immersion. Accessed February 10, 2017. https://www.binghamton.edu/freshman-research-immersion/index.html.

[34] Capobianco, B.M., French, B. F., & Diefes-Dux, H. A., 2012, “Engineering identity development among pre-adolescent learners,” *Journal of Engineering Education*, 101(4), p. 698.

[35] Tonso K.L., 2014, "Engineering identity," in *Cambridge Handbook of Engineering Education Research*, New York, NY, Cambridge University Press, pp. 267-282.

[36] Tonso, K.L., 2007. *On the outskirts of engineering: Learning identity, gender, and power via engineering practice*. Sense Publishers.

[37] Marra, R.M., Rodgers, K. A., Shen, D., & Bogue, B., 2009, “Women engineering students and self-efficacy: A multi-year, multi-institution study of women engineering student self-efficacy,” *Journal of Engineering Education*, 98(1), pp. 27-38.

[38] Meyers, K. L., Ohland, M.W., Pawley, A. L., Silliman, S. E., & Smith, K. A., 2012, “Factors relation to engineering identity,” *Global Journal of Engineering Education*, 14(1), pp. 119-131.

[39] Brophy, S., Klein, S., Portsmore, M., & Rogers, C., 2008, “Advancing engineering education in P-12 classrooms,” *Journal of Engineering Education*, 97(3), p. 369.

APPENDIX A

LECTURE SCHEDULE

Week	Lecture Number	Topic
1	1	**Introduction to FIRE, ME Background, FIRE Project Overview** *Introduction to FIRE—* • Course administration, syllabus details (assignments, grading, etc.), lecture schedule • Intent of the course, motivations *ME Background—* • Brief overview of the various areas of mechanical engineering (acoustics, biomechanical engineering, dynamic systems & control, manufacturing & design, materials science, nuclear & radiation engineering, thermal fluid sciences) • Provide example topics in each area, referencing the current semester offerings if there is association • Also provide key faculty members in these fields *FIRE Projects Overview—* • Discuss the background of each of the research projects that are offered for the semester • Provide the sponsoring faculty's name (encourage students to research these individuals, but to refrain from contacting them at this point) • Provide some details on what each project's prospective end result/deliverable (by the end of the semester) will be
3	2	**Overview of the Research Process** • Discuss the methodology for conducting research • Formulating hypotheses • Design of experiments • Use of theoretical/analytical and experimental modeling • Analysis and synthesis of data • Common roadblocks (lecturer can speak from personal experience or relay experiences from colleagues) and how to overcome them
5	3	**Student Presentations on Research Background & Plans** 5 minute team presentation by each project team: • Research Project Background • Research Plan • Current Progress
7	4	**(Guest Lecture) Current Topics in Engineering Research** • Invite a faculty member (perhaps one who is not mentoring a project to provide variety) to discuss their research, personal experiences, and lessons learned
9	5	**(Guest Lecture) Topics in Engineering Education: Graduate School** • Invite a graduate student or post-doctoral scholar to discuss their educational path, research, motivations, and lessons learned
11	6	**Professional Skills for Communicating Engineering Research** • Discuss the guidelines for the final research reports and presentations
13	N/A	**[Holiday] – No Lecture**[1]
15	7	**Final Student Presentations** 7 minute team presentation by each project team (with 3 minutes Q&A): Process, Results, Deliverables

[1] If there is no holiday observed this lecture could focus on engineering careers (outside of academia) where a guest lecturer could be an individual working as an engineer in the field. The specific industry is not particularly critical, but it is important to find an individual who is passionate about their work and holds a position which fully utilizes their engineering degree (a past speaker for FIRE was an engineer for SpaceX in McGregor, TX). A former student adds a level of connection because they can speak from directly relatable past experiences.

APPENDIX B

MENTOR-TEAM CHARTER TEMPLATE

Freshman Introduction to Research in Engineering (FIRE) Mentor-Team Charter

The purpose of this charter is to encourage teammates and mentors to have an open and comprehensive discussion about goals, expectations, and responsibilities for the semester-long project. Feel free to edit and add/remove aspects per your discussions to create a charter with which all parties are comfortable. Please complete the MSWord document and expand each section as needed.

Names of Team Members:

Name(s) of Mentor(s):

Goals and Objectives for the Semester-long Project:

- Our research project goal is:

- We intend to achieve the following milestones during the course of the semester: (include rough dates as necessary):

- Overall project success will be determined by:

- Additional guidance and mentorship can be obtained by contacting the following individuals (as needed):

- We will meet ___ times a week, at ____________AM/PM, unless otherwise agreed upon. Changes to meeting times will be communicated by e-mail/phone/other:___________ at least _____ hours in advance.

General Expectations for Successful Teamwork:

Below are some more general expectations for successful teamwork. Please discuss with your team and mentor and modify to represent your mutual expectations.

I will:

- Treat my teammates and mentor(s) with respect and courtesy, with the understanding that we are working collaboratively toward a common goal.
- Be honest and open during meetings and in discussions, including speaking up when assistance or guidance is needed.
- Focus on what is best for the research project by being open to new approaches, listening to new ideas, and doing my part to create an environment that encourages diverse thinking and allows everyone an equal opportunity to participate.
- Be committed to seeing this project through to completion.
-

-
-

All Parties Initial Here:

APPENDIX C

RESEARCH PAPER AND POSTER GUIDELINES

Final Poster Presentation
Prepare MS Powerpoint slides for a final poster presentation. The final poster presentation will be held on Friday, December 4, 3-5 PM, in the T-room on the 2nd floor of ETC. The teaching team will provide rigid poster boards for mounting and organizing your presentation. Please bring paper copies of up to 10 slides. The first slide should be a title slide with the title of your project, your faculty advisor's name, the names of your team members, the name of the class, and the date. The remaining 9 slides should describe the project itself, starting with the description of the problem or challenge, providing some background information on the problem and how you approached it, and describing your findings and final results. (You may use fewer than 9 slides if you prefer.) Each team will have an opportunity to present their poster to the class and invited guests. Please limit your presentation to a maximum of 7 minutes, followed by 2-3 minutes of Q&A. The 7 minute time limit will be strictly enforced so that everyone can present in the 2 hour time frame. It is preferable for all members of your team to share the speaking responsibilities.

Final Report
Prepare a final report describing your semester-long project. If you are a member of a group, your target length for the report should be approximately 4000 words. If you are working by yourself, your target length should be approximately 2000 words. These word limits are suggestions; you will not be penalized for writing longer reports, but it will be difficult to cover the entire project with significantly fewer words. A suggested outline for your report:

Abstract
Approximately 100-200 words summarizing your project and your final reults.

Introduction
Introduce your project, the motivation for it, and any background information describing why the project is important and how it fills a gap in our capabilities or knowledge.

Methods
Describe the methods and/or process you used to carry out your project. It is OK to describe false starts or dead ends if you tried multiple strategies before settling on a successful approach.

Results
Describe the results of your project, including any final deliverables, prototypes, etc.

Conclusion
Summarize your achievements over the course of the semester. Suggest opportunities for future work.

Appendix
Include any additional documentation, such as copies of your software (if you're coding things yourself), data sheets, CAD drawings, and survey results.